

What is claimed is:

1. A multi-function bundle, comprising:
  - a plurality of fuel cells;
  - an oxidant supply system;
  - a fuel supply system;
  - a fuel reformation system; and
  - a support structure for enabling said plurality of fuel cells, said oxidant supply system, said fuel supply system, and said fuel reformation system to operate as an integrated unit.
2. The multi-function bundle of claim 1 wherein at least one of said oxidant supply system, said fuel supply system, and said fuel reformation system is fully distributed.
3. The multi-function bundle of claim 1 wherein said oxidant supply system further comprises:
  - a plurality of oxidant feed tubes; and
  - an exhaust/air distribution chamber for supplying oxidant to said plurality of oxidant feed tubes.
4. The multi-function bundle of claim 3 wherein each of said plurality of fuel cells is associated with at least one of said plurality of oxidant feed tubes.
5. The multi-function bundle of claim 1 wherein said fuel supply system further comprises:
  - a fuel box having a plurality of holes therein for distributing fuel to said plurality of fuel cells;
  - a manifold for supplying fuel to said fuel box, said manifold having an entrance port.
6. The multi-function bundle of claim 5 wherein said fuel supply system further comprises a cast insulation material operable to seal said manifold within said fuel box.
7. The multi-function bundle of claim 5 wherein said fuel reformation system further comprises one or more fuel feed tube assemblies each having an entrance leg located within one of said plurality of holes within said fuel box.

8. The multi-function bundle of claim 7 wherein said plurality of fuel feed tube assemblies includes a fuel reformation catalyst.
9. The multi-function bundle of claim 7 wherein each of said plurality of fuel cells is associated with at least one of said plurality of fuel feed tube assemblies.
10. The multi-function bundle of claim 1 wherein said plurality of fuel cells are elongated annular solid oxide fuel cells having an oxidant electrode and a fuel electrode separated by an electrolyte, wherein at least one end of said solid oxide fuel cells is closed and wherein said oxidant electrode and said fuel electrode each have an electrical connection attached thereto.
11. The multi-function bundle of claim 1 further comprising one or more electrical connectors operable to electrically connect two or more of said plurality of fuel cells.
12. The multi-function bundle of claim 11 wherein said one or more electrical connectors is comprised of an elongated conductive strip having a first contact for coupling with a first fuel cell and a second contact for coupling with a second cell.
13. The multi-function bundle of claim 12 wherein at least one of said first and said second contacts is curved to couple with the curvature of an outside surface of one of said first and second fuel cells.
14. The multi-function bundle of claim 1 wherein said support structure includes at least one of an exhaust/air distribution box, a recirculation box, a fuel box, a cell spacer, and a cell and fuel feed spacer.
15. The multi-function bundle of claim 14 wherein at least one of said exhaust/air distribution box, said recirculation box, said fuel box, said cell spacer, and said cell and fuel feed spacer includes a tongue-and-groove connector.
16. The multi-function bundle of claim 1 wherein said support includes at least one of an upper cell spacer plate, a lower cell spacer plate, an air tube spacer plate, chamber supports, a reformer box, seal locator strips, and a cell and fuel feed spacer.

17. The multi-function bundle of claim 1 further comprising an outer shell.
18. A multi-function bundle, comprising:
  - an elongated annular fuel cell having an oxidant electrode and a fuel electrode separated by an electrolyte;
  - an oxidant feed tube operable to supply an oxidant to said oxidant electrode;
  - a fuel feed tube assembly operable to supply fuel to said fuel electrode; and
  - a support structure for enabling said elongated annular fuel cell, said oxidant feed tube, and said fuel feed tube assembly to operate as a modular unit.
19. The multi-function bundle of claim 18 further comprising one or more electrical connectors operable to electrically connect two or more of said plurality of fuel cells.
20. The multi-function bundle of claim 19 wherein said one or more electrical connectors is comprised of an elongated conductive strip having a first contact for coupling with a first fuel cell and a second contact for coupling with a second cell.
21. The multi-function bundle of claim 20 wherein at least one of said first and said second contacts is curved to couple with the curvature of an outside surface of one of said first and second fuel cells.
22. The multi-function bundle of claim 18 wherein said fuel cell is a solid oxide fuel cell and wherein said oxidant electrode and said fuel electrode each have an electrical connection attached thereto.
23. The multi-function bundle of claim 18 wherein said fuel feed tube assembly comprises an inlet leg in fluid communication with an outlet leg to form a flow path.
24. The multi-function bundle of claim 23 wherein said fuel feed tube assembly further comprises a support fin.
25. The multi-function bundle of claim 24 wherein at least one of said input leg, said output leg, and said support fin includes a fuel reformation catalyst material.
26. The multi-function bundle of claim 23 wherein said inlet leg comprises a first elongated sleeve having an inlet and an outlet, wherein said outlet leg comprises a

second elongated sleeve having an open end and a closed end, and wherein said first elongated sleeve is nested inside said second elongated sleeve, said first elongated sleeve and said second elongated sleeve being in fluid communication to form a flow path.

27. The multi-function bundle of claim 26 wherein said first elongated sleeve is separated from said second elongated sleeve by at least one support fin.
28. The multi-function bundle of claim 18 wherein said support structure includes at least one of an exhaust/air distribution box, a recirculation box, a fuel box, a cell spacer, and a cell and fuel feed spacer attached to said plurality of fuel cells.
29. The multi-function bundle of claim 28 wherein at least one of said exhaust/air distribution box, said recirculation box, said fuel box, said cell spacer, and said cell and fuel feed spacer includes a tongue-and-groove connector.
30. The multi-function bundle of claim 18 wherein said support structure includes at least one of an upper cell spacer plate, a lower cell spacer plate, an air tube spacer plate, chamber supports, a reformer box, seal locator strips, and a cell and fuel feed spacer.
31. A method for assembling a multi-function bundle, comprising:
  - attaching a recirculation box to a primitive bundle of fuel cells, said recirculation box being attached relative to an open end of said primitive bundle;
  - combining one or more oxidant feed tubes with an exhaust/air distribution box to form an oxidant feed tube – exhaust/air box assembly;
  - attaching said oxidant feed tube – exhaust/air box assembly to said primitive bundle of fuel cells, said oxidant feed tube – exhaust/air box assembly being attached relative to said open end of said primitive bundle;
  - combining a fuel box with one or more fuel feed tube assemblies to form a fuel feed tube – fuel box assembly; and
  - attaching said fuel feed tube – fuel box assembly to said primitive bundle of fuel cells, said fuel feed tube – fuel box assembly being attached relative to said closed end of said primitive bundle.

32. The method of claim 31 further comprising attaching a cell spacer to said primitive bundle of fuel cells, said cell spacer being attached relative to said open end of said primitive bundle.
33. The method of claim 31 further comprising attaching a cell and fuel feed spacer to said one or more fuel feed tube assemblies.
34. The method of claim 31 further comprising attaching a fuel distribution system to said fuel feed tube – fuel box assembly.
35. The method of claim 34 wherein said attaching a fuel distribution system further comprises:  
installing one or more fuel manifolds onto an inlet of said one or more fuel feed tubes; and  
casting a material around said fuel manifolds and said inlet of said one or more fuel feed tubes.
36. The method of claim 31 further comprising installing an outer shell around at least one of said primitive bundle, said exhaust/air distribution box, said recirculation box, said one or more oxidant feed tubes, said one or more fuel feed tubes, and said fuel box.
37. The method of claim 31 wherein said combining one or more oxidant feed tubes with an exhaust/air distribution box to form an oxidant feed tube – exhaust/air box assembly further comprises placing a porous washer onto each of said one or more air feed tubes.
38. A fuel cell stack, comprising:  
a plurality of multi-function bundles arranged in one or more rows and columns, wherein each of said plurality of multi-function bundles comprises:  
a plurality of fuel cells;  
an oxidant supply system;  
a fuel supply system;  
a fuel reformation system; and

a support structure for enabling said plurality of fuel cells, said oxidant supply system, said fuel supply system, and said fuel reformation system to operate as an integrated unit.

39. The fuel cell stack of claim 38 wherein at least one of said oxidant supply system, said fuel supply system, and said fuel reformation system is fully distributed.
40. The fuel cell stack of claim 38 wherein said oxidant supply system further comprises:
  - a plurality of oxidant feed tubes; and
  - an exhaust/air distribution box for supplying oxidant to said plurality of oxidant feed tubes.
41. The fuel cell stack of claim 40 wherein each of said plurality of fuel cells is associated with at least one of said plurality of oxidant feed tubes.
42. The fuel cell stack of claim 38 wherein said fuel supply system further comprises:
  - a fuel box having a plurality of holes therein for distributing fuel to said plurality of fuel cells;
  - a manifold for supplying fuel to said fuel box, said manifold having an entrance port.
43. The fuel cell stack of claim 42 wherein said fuel supply system further comprises said fuel supply system further comprises a cast insulation material operable to seal said manifold within said fuel box.
44. The fuel cell stack of claim 42 wherein said fuel reformation system further comprises one or more fuel feed tube assemblies each having an entrance leg located within one of said plurality of holes within said fuel box.
45. The fuel cell stack of claim 44 wherein said plurality of fuel feed tube assemblies includes a fuel reformation catalyst.
46. The fuel cell stack of claim 44 wherein each of said plurality of fuel cells is associated with at least one of said plurality of fuel feed tube assemblies.

47. The fuel cell stack of claim 38 wherein said support structure includes at least one of an exhaust/air distribution box, a recirculation box, a fuel box, a cell spacer, and a cell and fuel feed spacer attached to said plurality of fuel cells.
48. The fuel cell stack of claim 47 wherein at least one of said exhaust/air distribution box, said recirculation box, said fuel box, said cell spacer, and said cell and fuel feed spacer includes a tongue-and-groove connector.
49. The fuel cell stack of claim 38 wherein said support structure includes at least one of an upper cell spacer plate, a lower cell spacer plate, an air tube spacer plate, chamber supports, a reformer box, seal locator strips, and a cell and fuel feed spacer.
50. The fuel cell stack of claim 38 further comprising:  
an exhaust system operable to interface with a combustion chamber of said exhaust/air distribution box of one or more of said plurality of multi-function bundles;  
and  
a recirculation system operable to interface with said recirculation box of one or more of said plurality of multi-function bundles.
51. The fuel cell stack of claim 38 further comprising an outer shell.
52. The fuel cell stack of claim 51 wherein said outer shell includes:  
a lower end/side piece surrounding a lower portion of said arrangement of said plurality of multi-function bundles;  
a lower band for holding said lower end/side piece relative to said lower portion of said arrangement;  
a riser end/side piece surrounding a middle portion and a top portion of said arrangement; and  
an upper band for holding said riser end/side piece relative to said middle portion and said upper portion of said arrangement.
53. A pressure containment vessel, comprising:  
a base for supporting a plurality of multi-function fuel cell bundles; and  
a cover having a side wall and a domed top, said domed top having one or more corrugations.

54. The pressure containment vessel of claim 53 wherein said domed top has one or more concentric, spherical end-ring corrugations.
55. The pressure containment vessel of claim 53 wherein said base comprises:  
a base plate; and  
a substantially spherical outer wall for supporting said base plate.
56. The pressure containment vessel of claim 54 wherein said base further comprises one or more supports for transferring the weight of said base plate to said spherical outer wall.
57. The pressure containment vessel of claim 56 wherein said base plate is substantially circular, said base plate being supported by a ledge around the perimeter of said spherical outer wall and by said supports.
58. The pressure containment vessel of claim 54 wherein said base plate is rigid.
59. The pressure containment vessel of claim 54 wherein said plurality of multi-function fuel cell bundles are carried by said base plate.
60. The pressure containment vessel of claim 59 wherein said base plate includes at least one of a reference pin and a single-plane location pin for aligning said plurality of multi-function fuel cell bundles relative to said base plate.
61. The pressure containment vessel of claim 53 wherein said plurality of multi-function fuel cell bundles are arranged in a stack, said stack including at least one lower end/side piece surrounding a lower portion of said arrangement of said plurality of multi-function bundles, a lower band for holding said lower end/side piece relative to said lower portion of said arrangement, at least one riser end/side piece surrounding a middle portion and a top portion of said arrangement, and an upper band for holding said riser end/side piece relative to said middle portion and said upper portion of said arrangement.
62. The pressure containment vessel of claim 53 further comprising at least one of:  
an air inlet port feed through for supplying air to said plurality of multi-function bundles;



a recirculation entrance port feed through for supplying a recirculated fuel mixture to said plurality of multi-function bundles;

a recirculation exit port feed through for transporting a depleted fuel mixture from said plurality of multi-function bundles;

an exhaust port feed through for transporting an exhaust stream from said plurality of multi-function bundles;

a positive electric terminal feed through for connecting a positive electric lead to said plurality of multi-function bundles; and

a negative electric terminal feed through for connecting a negative electric lead to said plurality of multi-function bundles.

63. A fuel cell engine, comprising:

a pressure containment vessel; and

one or more multi-function fuel cell bundles.

64. The fuel cell engine of claim 63 wherein said containment vessel comprises:

a base for supporting said one or more multi-function fuel cell bundles; and

a cover having a side wall and a domed top, said domed top having one or more concentric spherical end-ring corrugations.

65. The fuel cell engine of claim 64 wherein said base further comprises:

a base plate; and

a substantially spherical outer wall for supporting said base plate.

66. The fuel cell engine of claim 64 wherein said base further comprises one or more supports for transferring the weight of said base plate to said outer wall.

67. The fuel cell engine of claim 64 wherein said base plate is substantially circular and is supported by a ledge in the perimeter of said spherical outer wall and by said supports.

68. The fuel cell engine of claim 64 wherein said base plate is rigid.

69. The fuel cell engine of claim 64 wherein said plurality of multi-function fuel cell bundles are carried by said base plate.

70. The fuel cell engine of claim 63 wherein said containment vessel further comprising at least one of:
- an air inlet port feed through for supplying air to said one or more multi-function bundles;
  - a recirculation entrance port feed through for supplying a recirculated fuel mixture to said one or more multi-function bundles;
  - a recirculation exit port feed through for transporting a depleted fuel mixture from said one or more multi-function bundles;
  - an exhaust port feed through for transporting an exhaust stream from said one or more multi-function bundles;
  - a positive electric terminal feed through for connecting a positive electric lead to said one or more multi-function bundles; and
  - a negative electric terminal feed through for connecting a negative electric lead to said one or more multi-function bundles.
71. The fuel cell engine of claim 63 wherein said one or more multi-function fuel cell bundles comprise:
- a plurality of fuel cells;
  - an oxidant supply system;
  - a fuel supply system
  - a fuel reformation system; and
  - a support structure for enabling said plurality of fuel cells, said oxidant supply system, said fuel supply system, and said fuel reformation system to operate as an integrated unit.
72. The fuel cell engine of claim 71 wherein at least one of said oxidant supply system, said fuel supply system, and said fuel reformation system is fully distributed.
73. The fuel cell engine of claim 71 wherein said oxidant supply system further comprises:
- a plurality of oxidant feed tubes; and
  - an exhaust/air distribution box for supplying oxidant to said plurality of oxidant feed tubes.
74. The fuel cell engine of claim 73 wherein each of said plurality of fuel cells is associated with at least one of said plurality of oxidant feed tubes.

75. The fuel cell engine of claim 71 wherein said fuel supply system further comprises:  
a fuel box having a plurality of holes therein for distributing fuel to said plurality of fuel cells;  
a manifold for supplying fuel to said fuel box, said manifold having an entrance port.
76. The fuel cell engine of claim 75 wherein said fuel supply system further comprises a cast insulation material operable to seal said manifold within said fuel box.
77. The fuel cell engine of claim 75 wherein said fuel reformation system further comprises one or more fuel feed tube assemblies each having an entrance leg located within one of said plurality of holes within said fuel box.
78. The fuel cell engine of claim 77 wherein said plurality of fuel feed tube assemblies includes a fuel reformation catalyst.
79. The fuel cell engine of claim 77 wherein each of said plurality of fuel cells is associated with at least one of said plurality of fuel feed tube assemblies.
80. The fuel cell engine of claim 71 wherein said plurality of fuel cells are elongated annular solid oxide fuel cells having an oxidant electrode and a fuel electrode separated by an electrolyte, wherein at least one end of said solid oxide fuel cells is closed and wherein said oxidant electrode and said fuel electrode each have an electrical connection attached thereto.
81. The fuel cell engine of claim 71 further comprising one or more electrical connectors operable to electrically connect two or more of said plurality of fuel cells.
82. The multi-function bundle of claim 81 wherein said one or more electrical connectors is comprised of an elongated conductive strip having a first contact for coupling with a first fuel cell and a second contact for coupling with a second cell.
83. The multi-function bundle of claim 82 wherein at least one of said first and said second contacts is curved to couple with the curvature of an outside surface of one of said first and second fuel cells.

84. The fuel cell engine of claim 71 wherein said support structure includes at least one of an exhaust/air distribution box, a recirculation box, a fuel box, a cell spacer, and a cell and fuel feed spacer attached to said plurality of fuel cells.
85. The fuel cell engine of claim 84 wherein at least one of said exhaust/air distribution box, said recirculation box, said fuel box, said cell spacer, and said cell and fuel feed spacer includes a tongue-and-groove connector.
86. The multi-function bundle of claim 71 wherein said support structure includes at least one of an upper cell spacer plate, a lower cell spacer plate, an air tube spacer plate, chamber supports, a reformer box, seal locator strips, and a cell and fuel feed spacer
87. The fuel cell engine of claim 84 wherein said pressure containment vessel includes an exhaust port feed through, an air inlet port feed through, a recirculation entrance port feed through, and a recirculation exit port feed through, and wherein said exhaust/air distribution box is operable to interface with said exhaust port feed through and said air inlet port feed and wherein said recirculation box is operable to interface with said a recirculation entrance port feed through, a recirculation exit port feed through.
88. An assembly, comprising:  
    an entrance leg;  
    a return leg; and  
    a support fin, wherein said entrance leg, return leg, and support fin form a counter-flow heat exchanger and wherein said entrance leg and said return leg define a flow path.
89. The assembly of claim 88 wherein at least one of said entrance leg, said return leg, and said support fin includes a fuel reformation catalyst material.
90. The assembly of claim 88 wherein said entrance leg is nested inside said return leg.
91. The assembly of claim 88 wherein said entrance leg is separated from said return leg by said support fin.

92. The fuel feed tube assembly of claim 88 wherein said entrance leg, said return leg, and said support fin are extruded from a single piece of material.
93. A device for electrically connecting two or more tubular fuel cells, comprising:  
an elongated conductive strip having a first contact for coupling with an a first tubular first fuel cell and having a second contact for coupling with a second tubular fuel cell.
94. The device of claim 93 wherein said first contact is curved to couple with the curvature of an outer surface of said first tubular fuel cell.
95. The device of claim 94 wherein said second contact is curved to couple with the curvature of an outer surface of said second tubular fuel cell.
96. The device of claim 95 wherein said elongated conductive strip includes a third contact for coupling with a third tubular fuel cell and a fourth contact for coupling with a fourth tubular fuel cell.
97. The device of claim 96 wherein said third contact is curved to couple with the curvature of an outer surface of said third tubular fuel cell and wherein said fourth contact is curved to couple with an outer surface of said fourth tubular fuel cell.
98. The device of claim 96 wherein the outer surface of at least one of said first, second, third, and fourth tubular fuel cells is one of a fuel electrode, an oxidant electrode and an electrical interconnect.
99. The device of claim 93 wherein said second contact is comprised of a plurality of interleaved fingers.
100. The device of claim 93 wherein said elongated conductive strip is made from at least one of nickel, aluminum, and copper.